LORD KELVIN.

By H. C. Plummer.

The death of Lord Kelvin, which occurred in the closing days of the past year, concerns primarily that science the progress of which he did so much to mould, but also, in a scarcely less degree, all those sciences which are largely dependent on the development of the fundamental principles of natural philosophy, and among these not least astronomy. A dominant figure among men of science throughout the latter half of the nineteenth century, and, since the death of v. Helmholtz, in 1894, beyond dispute the greatest living physicist, he has passed away in the full fruition of his genius at the venerable age of eighty-three years. Those who had the privilege of listening to him so lately as last August at the Leicester meeting of the British Association will not easily forget his inspiring example or how perfectly his mental powers were maintained to the end of his long life. Indeed, the mature power manifested in his early youth, the youthful enthusiasm of his old age, and the life of unwearied achievement which lay between, are alike remarkable in a brilliant career.

William Thomson was born at Belfast in June, 1824. His father, at that time professor of mathematics in the Belfast Academical Institution, was called, eight years later, to fill the chair of mathematics in Glasgow University. This was the beginning of that long and memorable association with the ancient Scottish seat of learning which enabled Lord Kelvin to say truly, on the occasion of his installation as Chancellor three years ago: "I am a child of the University of Glasgow. I lived in it sixty-seven years (1832 to 1899)." In the same address he has drawn a fascinating picture of the university in the thirties, and of his own early studies there. His precocious abilities were truly astonishing, and there can be no doubt but that he had the good fortune to be placed in an environment which fostered them to the utmost. He was matriculated in 1834, at the age of ten, and studied Latin under William Ramsay, Greek under Sir Daniel Sandford and Lushington, logic under Robert Buchanan, and moral philosophy under William Fleming. From his father he

learned mathematics and much else besides, from WILLIAM COUPER zoology and geology, and from THOMAS THOMSON chemistry. The latter, "a very advanced teacher and investigator," had already realized a well-equipped laboratory, which preceded LIEBIG's famous laboratory at Giessen. As regards his indebtedness to his teachers in natural philosophy, Lord KELVIN's own tribute may be quoted: "My predecessor in the natural philosophy chair, Dr. MEIKLEHAM, taught his students reverence for the great French mathematicians, LEGENDRE, LAGRANGE, LAPLACE. His immediate successor in the teaching of the natural philosophy class, Dr. NICHOL, added FRESNEL and FOURIER to this list of scientific nobles; and by his own inspiring enthusiasm for the great French school of mathematical physics, continually manifested in his experimental and theoretical teaching of the wave theory of light and of practical astronomy, he largely promoted scientific study and thorough appreciation of science in the University of Glasgow." The youthful student made splendid use of splendid opportunities; he repaid them by lifelong devoted service and added luster to an illustrious foundation.

The years that followed at Cambridge seem only an incident in the career of one who had already read something of the "Théorie analytique de la Chaleur" before his sixteenth birthday. WILLIAM THOMSON was second wrangler in the tripos of 1845, and first Smith's Prizeman in the same year. He was immediately elected to a fellowship at his own college, Peterhouse, but he was not destined to remain at Cambridge. In the following year, after working for a time at Paris, in the laboratory of REGNAULT at the Collége de France, he was elected, at the age of twenty-two, to succeed Dr. MEIKLEHAM in the chair of natural philosophy at Glasgow. This office he filled continuously for fifty-three years, until his resignation in 1899.

Space forbids a detailed reference to the brilliant and many-sided work of original discovery which Lord KELVIN crowded into this memorable period of scientific history. Much is matter of common knowledge; many excellent notices have been published since his death, and it is understood that an authentic biography by Professor SILVANUS THOMPSON is to appear shortly. Even if the view is restricted to the astronomical standpoint, and an attempt is made to appraise the

debt which astronomy owes to Lord KELVIN'S work, the points of direct contact and of indirect influence are so manifold that they enforce his own dictum, that all science is one science and that any part of science which places itself outside the pale of the other sciences ceases for the time being to be a science. Thus he served the cause of submarine telegraphy alike by the theoretical discussion of the conditions of the problem, by the invention of practical receiving apparatus, and by his indomitable scientific faith at a time when AIRY declared an Atlantic cable to be on mechanical and electrical grounds impossible; and while the realization of the cable is a benefit to humanity at large, the astronomer incidentally owes to it the fact that the ocean has been no longer a barrier to accurate determinations of longitude. The mirror galvanometer, again, which constituted his earlier form of receiving apparatus, has found innumerable applications; perhaps its most direct service to astronomy is to be seen in LANGLEY'S use of it as an essential part of his bolometer. These examples are quoted merely to show that there is scarcely any part of Lord KELVIN'S activity which is not of interest to the astronomer. His researches covered the whole field of electricity and magnetism, ranging from developments in the subject of electrostatics, with the beautiful theory of images, to the invention of numerous instruments for precise measurement, used in every physical laboratory and by every electrical engineer, and so perfectly designed as to remain unchanged even in detail.

For work in the theory of heat Lord KELVIN was particularly well fitted by his early training and by his association, brief though it was, with REGNAULT. He was also fortunate in the friendship and co-operation of JOULE. In this field some of his best and most original work was done, both on the theoretical and the experimental side. By his restatement of the second law of thermodynamics, by his definition of an absolute thermodynamic scale of temperature, and by his discovery of the principle of the dissipation of energy, he is entitled, along with CLAUSIUS, to rank as one of the founders of thermodynamics. On the experimental side his best work was the "porous-plug experiment" carried out in conjunction with JOULE, and his researches in thermo-electricity, including the discovery of the "Thomson effect." By applying the analysis of FOURIER to the consideration of the thermal con-

dition of the Earth, Lord KELVIN was led to announce his famous limit to its possible age as a habitable planet. This brought about the celebrated conflict with the uniformitarians, and has exercised a profound influence on the thoughts of geologists. The opposing views were never entirely reconciled, and the question at issue has been reopened by the recent discovery of sub-atomic sources of energy. The same question is also involved to some extent in Sir GEORGE DARWIN'S theory of the evolution of the Earth-Moon system.

The problem of the age of the Earth is only one aspect of that presented by the mechanical energies of the solar system which in all its generality occupied Lord KELVIN'S attention from an early date. He first examined the theory that the heat of the Sun was maintained by the influx of meteoric matter from outer space, and rejected it after a careful quantitative estimate on the ground that the number of meteors required to supply the loss of heat by solar radiation is enormously in excess of what is compatible with terrestrial experience. He then adopted the suggestion of v. HELMHOLTZ, that the energy emitted in a radiant form was gained by the contraction of the Sun's mass at the expense of gravitative potential energy. This doctrine, to which HOMER LANE contributed in this country, led him to investigate the conditions of a spherical mass of gas in convective equilibrium. There are many obstacles in the way of adapting this theory to actual stellar conditions, and the difficulty of drawing definite conclusions has not been diminished by the new possibilities presented by the energy set free in radio-active transformations; but of the suggestive importance of the theory there can be no doubt.

Many investigations were made by Lord KELVIN in the region of hydrodynamics, and his work on tides is of great importance. To him and to Sir GEORGE DARWIN is due the fact that tidal theory is now practically perfect. The part which he took in devising mechanical means for calculating tides resulted in a practical labor-saving machine for predicting the tides of the Indian Ocean. He also designed a tide recorder and a harmonic analyzer. Graphical and mechanical methods of performing calculations, and in particular of solving differential equations, possessed much interest for him, and it may be noted that the method of mechanical quadratures employed by Sir GEORGE DARWIN in his memoir on Periodic

Orbits is the numerical counterpart of a graphical method described by Lord KELVIN. Of great interest to the astronomer are his researches regarding the physical condition of the Earth, in which, by masterly use of the results of tidal observations and of the theory of nutation, he arrived at definite conclusions as to the rigidity of the external and internal substance of the Earth. The stimulus derived from personal intercourse with Professor NEWCOMB led him farther to examine the possible variation in the diurnal period and axis of rotation, some fifteen years before the accurate observations of Professor KÜSTNER and the comprehensive discussions of Dr. CHANDLER had revealed the true nature of the problem of the variation of latitude.

Lord KELVIN was himself a keen yachtsman, and to the art of navigation he has rendered immense services by applying his inventive genius to its needs. By observing true scientific principles he invented and manufactured the standard type of mariner's compass. His apparatus for sounding by means of pianoforte-wire is as simple as it is effective. As regards the astronomical side of the seaman's art, he advocated the use of SUMNER's method for finding a ship's place at sea, and published tables to facilitate its application. Here it may be recalled that he wrote several papers on chronometers and clocks, including electrical controls, especially an important one in which he discussed the effect on the rate of the form of suspension. One contribution he made to purely practical astronomy: this was a photometric study of the Sun and Moon and a comparison of their light with terrestrial standards.

In conjunction with the late Professor TAIT, Lord KELVIN wrote the classic "Treatise on Natural Philosophy," which was translated by v. HELMHOLTZ, and has been used as a text-book perhaps even more extensively in Germany than in England. The responsibility for the abbreviated title, "T and T′" has been variously assigned. The breadth of view and the stimulating interest of these two volumes must cause a regret that a scheme so brilliantly begun was not carried farther. But it is matter for satisfaction that Lord KELVIN lived to amplify and to publish his "Baltimore Lectures" twenty years after the date of their delivery (in 1884) at the Johns Hopkins University. Here are to be found in a collected form the final results of his researches in molecular dynamics and the wave

theory of light, more particularly concerning the dynamical theory of dispersion. Of late years much of his thought was devoted to the ultimate structure of matter and the true nature of the æther. It would be idle to pretend that his views on these matters towards the end of his life gained very general assent. The *i* which he persistently retained in the word "electrion" seemed symbolical of a certain divergence on his part from the main stream of contemporary thought. And indeed his death significantly marks an epoch in scientific history. The school of which he was so brilliant an example was not content with anything less than a complete dynamical explanation of phenomena. This phase of scientific positivism is passing away, and the tendency since the publication of CLERK MAXWELL's electromagnetic theory has been unmistakably, if perhaps too hastily, more and more in the direction of "æther and no matter," to quote Professor LAMB's parody of the title of Professor LARMOR's book.

Yet, if the whole of Lord KELVIN's ideas are not destined to find acceptance, his possible weakness is closely allied to the great source of his strength, his passion for the concrete. The man who makes no mistake makes nothing, and no man ever more ruthlessly destroyed the creatures of his own fertile brain, when he deemed them to have become erroneous or useless, than Lord KELVIN. Of him v. HELMHOLTZ wrote thirty years ago: ". . . he has done very much to destroy the old unnatural separation between experimental and mathematical physics, and to reduce the latter to a precise and pure expression of the laws of phenomena. He is an eminent mathematician, but the gift to translate real facts into mathematical equations, and *vice versa,* is by far more rare than that to find the solution of a given mathematical problem, and in this direction Sir WILLIAM THOMSON is most eminent and original." It has been denied that he is to be regarded as a mathematician in the strict sense. It is true, perhaps, that in his own branch he was not the equal in this respect of v. HELMHOLTZ himself, or of STOKES, to mention no others; but the complete denial of his claim rests upon the restriction of the word "mathematics" to the pure variety. As a logical distinction this may be harmless enough, but if the idea is extended in the region of education to the practical separation of the pure and applied branches the result is likely to be unfortunate

for both. There is little doubt that without the due co-operation of the two the Cambridge school of mathematical physicists would have been shorn of its chief glories.

Lord KELVIN had traveled widely and had made several visits to this country. The last was in 1902, when he received a generous and enthusiastic welcome, which will be within the memory. Some of the impressions which he received during a visit in 1876 are recorded in his presidential address to Section A of the British Association in the same year, and some of his words on that occasion may be of interest:—

". . . I wished to write an address of which science in America should be the subject. I came home, indeed, vividly impressed with much that I had seen, both in the great exhibition of Philadelphia and out of it, showing the truest scientific spirit and devotion, the originality, the inventiveness, the patient persevering thoroughness of work, the appreciativeness, and the generous open-mindedness and sympathy, from which the great things of science come. . . .

"I wish I could speak to you of the veteran HENRY, generous rival of FARADAY in electromagnetic discovery; of PEIRCE, the founder of high mathematics in America; of BACHE, and of the splendid heritage he has left to America and to the world in the United States Coast Survey; of the great school of astronomers which followed, GOULD, NEWTON, NEWCOMB, WATSON, YOUNG, ALVAN CLARKE, RUTHERFORD, DRAPER, father and son;" nor does the passage end here. Only those who have heard Lord KELVIN speak will be able to realize the glow of enthusiastic sincerity with which such a tribute would be uttered.

Many years ago it was said that "in Sir WILLIAM THOMSON the most brilliant genius of the investigator is associated with the most lovable qualities of the man. His single-minded enthusiasm for the promotion of knowledge, his wealth of kindliness for younger men and fellow-workers, and his splendid modesty, are among the qualities for which those who know him best admire him most." These qualities were only enhanced with advancing years. Withal, he was endowed with the shrewd business capacity of his race, and not only personally supervised the manufacture of his numerous patents but also acted as a director of several public companies. He was conservative to the core—and that not merely in the

political sense. This is to be seen in his strict adherence to NEWTON'S formal enunciation of the principles of dynamics, though his colleague TAIT was more outspoken in his denunciation of any departure from the Newtonian position. The advocates of the retention of compulsory Greek in the ancient universities were also able to quote in their favor an opinion bearing all the weight of Lord KELVIN'S authority, and, it may be added, in the light of his early training, of his personal experience.

Great and varied were his talents, and worthily he used them for the benefit of mankind. All the successes, all the honors, that could fall to the lot of a man of science were his. He was president of the British Association in 1881, and in succession to Sir GEORGE STOKES was president of the Royal Society from 1890 to 1895. Nowhere will his presence be more keenly missed than at the annual meetings of the British Association, which he attended so assiduously. His connection with his own University of Glasgow was crowned by his election as Chancellor in 1904. On his return from the laying of the first successful Atlantic cable, in 1866, his services to the state were rewarded with a knighthood; later, in 1892, he was raised to the peerage under the title of Baron KELVIN of Largs. When the Order of Merit was instituted by King Edward, in 1902, he was chosen as one of the first members of that select band. Other decorations, British and foreign, were showered upon him. The learned societies of his own and other countries had done him such honor as lay within their power. And the last solemn distinction which England has to bestow was reserved for him. Amid a scene which the December gloom of a London day served only to render the more impressive, in the presence not only of representatives of the King, of foreign governments, of the whole world of learning, but also of vast numbers who must have felt a deep sense of personal loss, he was laid to rest in Westminster Abbey. There he finds a place in close proximity to him whom he would be the first to acknowledge as his master, ISAAC NEWTON. His fame is secure in the comprehensive influence which he exercised on the scientific progress of his generation; his is the *"monumentum ære perennius."*